NAVAL POSTGRADUATE SCHOOL
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THESIS

AN ANALYSIS OF AUDITORY CUES FOR INCLUSION IN A VIRTUAL CLOSE QUARTERS COMBAT ROOM CLEARING OPERATION

by

Thomas W. Greenwald

September 2002

Thesis Advisor: Russell D. Shilling
Co-Advisor: Rudy P. Darken

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This thesis uses the Critical Decision Method of knowledge elicitation to obtain an auditory Critical Cue Inventory from room clearing subject matter experts. Those experts will then conduct a virtual room clearing operation using the game America's Army: Operations, and compare the auditory cues presented in the game scenario to the real-world execution of the task.

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AN ANALYSIS OF AUDITORY CUES FOR INCLUSION IN A VIRTUAL CLOSE QUARTERS COMBAT ROOM CLEARING OPERATION

Thomas W. Greenwald
Major, United States Army
B.A., Texas A&M University, 1988

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September 2002

Author: Thomas W. Greenwald

Approved by: Russell D. Shilling
Thesis Advisor

Rudolph P. Darken
Co-Advisor

Rudolph P. Darken
Chair, MOVES Academic Committee

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ABSTRACT

The purpose of this thesis is to examine which auditory cues need to be included in a virtual representation of a Close Quarters Combat Room Clearing Operation. Future missions of the United States Armed Forces, especially those of the Army and Marine Corps, are increasingly likely to be conducted in cities or built-up areas. A critical need exists for MOUT (Military Operations in Urban Terrain) training by our armed forces, and the entire spectrum of military training needs to be addressed. Doctrine and principles, classroom instruction, drills, live fire exercises, as well as live and virtual simulation all have a part to play in developing an acceptable level of expertise in MOUT. The way in which training tasks are represented in a VE, including which audio cues must be presented, needs to be explored. This study will examine the auditory cues used during a MOUT mission and how those cues should be presented in a virtual MOUT scenario.

This thesis uses the Critical Decision Method of knowledge elicitation to obtain an auditory Critical Cue Inventory from room clearing subject matter experts. Those experts will then conduct a virtual room clearing operation using the game America's Army: Operations, and compare the auditory cues presented in the game scenario to the real-world execution of the task.

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I. INTRODUCTION

Future missions of the United States Armed Forces, especially those of the Army and Marine Corps, are increasingly likely to be conducted in cities or built-up areas. Well-trained and well-equipped Infantry forces are the key component for military success in urban environments (Sulzen, 1997). There has been a great deal of research over the past several years to better understand the challenges of Military Operations in Urban Terrain (MOUT). Such operations place great demands on military personnel for new types of technical skill. They also generate a peculiar set of cognitive requirements related to a wide range of judgments and decisions necessary in urban settings. Our military must be prepared for MOUT because the U.S. is a victim of its own successes. While our technical superiority will act as a deterrent for adversaries to engage us in conventional warfare, urban conflict offers attractive advantages to these potential adversaries. Urban warfare results in the potential loss of civilian life, destruction of important landmarks, ease of access for media coverage, and increased potential to inflict injuries on our soldiers with relatively unsophisticated weapons systems. In addition, the U.S. military has spent less time preparing for MOUT than for conventional warfare (Phillips, et al. 2001). As the likelihood of MOUT operations increases, the amount of training by U.S. forces to conduct these operations must also increase.

Obviously, a critical need exists for MOUT training by our armed forces, and the entire spectrum of military training needs to be addressed. Doctrine and principles, classroom instruction, drills, live fire exercises, as well as live and virtual simulation all have a part to play in developing an acceptable level of expertise in MOUT. Virtual Reality (VR) technology is beginning to have a large impact on military training. Units are no longer required to spend scarce resources (time and money) in preparation for and travel to large-scale training events and exercises. Soldiers are frequently able to train in simulators and experience many of the same effects as they would had they actually gone to the field. However, although sophisticated simulations can enhance military training, the technology still does not offer a veridical representation of the real world. There is an ongoing effort to determine exactly which individual and collective military tasks can be represented adequately in simulation (Salter, Eakin, & Knerr 1999). In addition to

determining which tasks to train using VEs, the VE must contain accurate perceptual stimuli and cues, including auditory cues.

Immersion in a VE has been defined as the "sense of actually being present in the virtual scenario" (Vince, 2001). Although there are many different methods to increase a user's sense of presence or immersion, among the most important are the sensory cues that are presented to the user. The greater the number of sensory inputs provided to different modalities, the greater the sense of presence (Lessiter, Freemen, & Davidoff 2001). Audio is a primary emotion-inducing medium in movie presentation and is said to comprise at least 50% of the motion picture experience (Holman, 2000). As the immersive qualities of a VE increase, the ability of VE participants to feel like they are actually present in the environment also increases. In most VEs, visual cues represent the majority of the sensory cues that lead to increased immersion. However, auditory cues have also been shown to play a crucial role in immersion (Sanders & Scorgie 2002). It is critical to determine exactly which auditory cues need to be presented in a training system or VE, and at what level of fidelity. Inversely, one needs to make certain that auditory cues that are not actually present in the environment are not placed in the VE. All auditory cues presented must be accurate and appropriate.

Why is it important to develop an accurate model of the auditory cues associated with a room clearing operation? In order to successfully conduct room clearing, all members of the team must achieve and maintain a high level of situational awareness. Situational awareness is the degree to which one is able to maintain a common operating picture of all aspects of the tactical situation. This picture includes an understanding of the friendly and enemy situation and the urban battle space. Since units will have to conduct operations in changing mission environments, it is imperative for commanders and leaders at all levels to achieve and maintain the best possible degree of situational awareness. Enhanced situational awareness will enhance lethality, survivability, and operational tempo (Department of the Army, 2002). The way that soldiers develop this common operating picture, or situational awareness, is by mentally combining all of the environmental cues received through their various senses.

Obviously, visual cues are critically important for creating an accurate mental image of one's environment. In certain circumstances, however, the auditory aspect of a

situation can be equally, if not more important, in understanding everything that is going on around you. Situational awareness in a room clearing operation can be characterized by one's understanding of two key aspects: 1) the enemy situation, and 2) the status of the friendly force. The room clearing team must locate the enemy in order to kill them, and must also prevent the enemy from locating and determining the mission and intent of the friendly team. When walls and other obscurants block the visual cues that would lead to this information, auditory cues become the primary means of developing situational awareness.

The room clearing team will use any auditory cues available to help develop a mental image. Any sounds that the enemy makes inside a room, footsteps, weapon noises, voices, whispers, rattling of equipment, will help the team members understand the enemy situation that they are about to face. Those same sounds, however, if made by the friendly force and heard by the enemy, can easily compromise the friendly mission and intent, and can lead to mission failure. An accurate virtual representation of a room clearing task must present these auditory cues in an accurate and appropriate way.

Some of the auditory cues associated with a real-world execution of a room clearing task are extremely loud. Weapons firing, explosions, grenades detonating, and people yelling will all have an impact on the people conducting the task. The effect of those loud noises must be examined and modeled in the virtual task representation. Tinnitus is a perceived ringing or some other kind of sound that is referred to the ear and cannot be traced to any external stimulus (Wever, 1949). This condition may be acute and temporary, as the result of excessive stimulation by a loud sound (Stevens & Davis, 1938). Temporary Threshold Shift (TTS) occurs after exposure to a loud noise, when the muscles of the middle ear contract in an effort to protect the ear from noise damage. This TTS temporarily degrades a person's ability to hear more subtle sounds after exposure to a very loud sound (Pickles, 1982). Again, an accurate virtual representation of a room clearing task must present these auditory cues in an accurate and appropriate way.

But how does one determine exactly what is accurate and appropriate for representing auditory cues in a room clearing operation? Obviously, in order to obtain insight into the real-world execution of the task, and what sounds are actually used by

experts in the room clearing domain, a knowledge elicitation technique involving real-world experts will have to be developed and utilized.

America's Army: Operations (AA:O) is a desktop-based videogame/virtual world representing life as a soldier in the United States Army. One of the levels in AA:O represents a mission that involves conducting a Close Quarters Battle (CQB) Room Clearing Operation in a MOUT setting. This MOUT scenario depicts a team of dismounted infantry soldiers entering a building in which some of the rooms are occupied by enemy soldiers. The friendly team must eliminate all hostile forces in the building, while protecting any non-combatants that may also be present. The findings of this study will be used as an analysis of auditory cues that need to be included in virtual representations of room clearing tasks.

A. THESIS OVERVIEW

This thesis will examine which auditory cues are associated with the performance of an actual Close Quarters Battle Room Clearing Operation, determine which of those cues need to be included in a virtual representation of that task, and explore the potential negative training transfer issues associated with incomplete or unrealistic auditory cues that may be presented in a virtual training environment.

1. Research Questions

- Which auditory cues need to be modeled in a Virtual Environment Close Quarters Battle Room Clearing Operation?
- What sound cues are associated with the performance of the actual task?
- Will the lack of certain auditory cues result in a negative training transfer from the virtual scenario to the real-world execution of the task?

2. Discussion

In order to make a virtual CQB room clearing operation as realistic and immersive as possible, an accurate description and model of the auditory cues associated with the real-world performance of the task must be made. Exclusion of key auditory cues or over-emphasis of non-critical auditory cues in the virtual scenario could result in reduced immersion and negative transfer of training to the real world execution of the task. Creating an accurate model of the auditory cues involved in the task is essential to preclude these problems.

The CQB room clearing task is extremely complex and typically of very short duration. Recognition of which auditory cues are actually used immediately prior to and during the task is critical to the development of an accurate auditory model. The end product of this thesis will be a Critical Cue Inventory (CCI) of all the auditory cues associated with a CQB room clearing operation. The CCI will present those auditory cues in a rank-ordered list from most important to least important for each subtask of the overall room clearing task. Once the auditory CCI of the real-world room clearing task is completed, it will be used to conduct an analysis of the auditory cues that are being presented in the America's Army: Operations representation of that task. In order to create the CCI, this thesis will use the Critical Decision Method to elicit domain specific knowledge from subject matter experts (SMEs) in the room clearing domain. These SMEs will be students at the Naval Postgraduate School who have developed a high degree of expertise in room clearing operations. The term expert generally refers to an individual who has over ten years experience and would be recognized as having achieved proficiency in the subject domain (Klein, Calderwood, & MacGregor, 1989). A structured interview that is created using the framework of the Critical Decision Method can provide specific feedback as to the auditory cues associated with each task and subtask of a given behavior. The CCI will be developed using the knowledge elicitation results obtained during the SME interviews. The CCI will provide a rank-ordered list of the auditory cues that need to be considered for inclusion in any virtual representation of the room clearing scenario.

After the Auditory Critical Cue Inventory is created, it will be used as a baseline for evaluating the auditory cues that are currently being presented in the room clearing scenario of AA:O. Some of the same SMEs who were interviewed to create the CCI will use it to document the auditory cues that they would expect to hear during a specific room clearing operation and then compare their expectations to the auditory cues that are actually presented as they conduct that operation in AA:O. Any differences between expectations of auditory cues in a real-world situation and auditory cues presented in the virtual situation will be examined for the potential to create a negative training transfer effect.

B. THESIS ORGANIZATION

This thesis is organized into the following chapters:

- Chapter I: Introduction. This chapter provides an overall outline of the thesis and describes the research objectives and motivation behind this research
- Chapter II: Background. This chapter reviews current U.S. doctrine concerning Military Operations on Urban Terrain (MOUT) and the auditory cues associated with room clearing operations, knowledge acquisition techniques, structuring techniques, and the Critical Decision Method.
- Chapter III: Subject Matter Expert Interview. This chapter describes the process used to recruit and interview room clearing subject matter experts, and presents the Auditory Critical Cue Inventory that resulted from the interviews.
- Chapter IV: Evaluation of Room Clearing Scenario. This chapter describes the procedures used to evaluate the auditory cues presented in a room clearing scenario in America's Army: Operations.
- Chapter V: Conclusions and Recommendations. This chapter provides a summary of the procedures used in this study and of the recommendations for the auditory cues to be presented in virtual room clearing scenarios. It also suggests potential future work in this area.
- Appendices:

  A. Interview.

  B. Mission Briefing and Maps.

  C. Participant Consent Forms.

II. BACKGROUND

A. MOUT TASK AND ASSOCIATED SOUND CUES

Before utilizing the Critical Decision Method to formulate a structured interview centered on any task, a cursory understanding of the task must be achieved. The task must be analyzed, understood, and broken down into sub-tasks that can be used as a framework for further investigation. The primary reference for MOUT issues in the U.S. Army and Marine Corps is FM 3-06.11 Combined Arms Operations In Urban Terrain (formerly FM 90-10-1 An Infantryman's Guide To Combat In Built-Up Areas). FM 3-06.11 defines Urban Operations (UO) as operations planned and conducted in an area of operations that includes one or more urban areas. An urban area consists of a topographical complex where man-made construction or high population density is the dominant feature. FM 3-06.11 defines Urban Combat as those offensive and defensive operations that include a high density of Infantry-specific tasks. Urban combat operations are conducted to defeat an enemy on urban terrain who may be intermingled with noncombatants. Engagements in a UO scenario are typically characterized as extremely rapid and violent. Engagement ranges are close. Studies and historical analyses have shown that only 5 percent of all targets are more than 100 meters away. About 90 percent of all targets are located 50 meters or less from the identifying soldier. Few personnel targets will be visible beyond 50 meters and they usually occur at 35 meters or less. Engagement times are short. Enemy personnel present only fleeting targets. Unless combat has been taking place in an urban area for an extended period of time, units will encounter large numbers of noncombatants. Noncombatants may be encountered during offensive operations as a result of clearing buildings and city blocks or when preparing for defensive operations.

MOUT scenarios present unique requirements for extreme clarity in situational awareness but also severely degrade the individual soldier's ability to use his own physical senses to enhance that situational awareness. Situational awareness is the degree to which one is able to maintain a common operating picture of all aspects of the tactical situation. Smoke, darkness, fog, rain, snow, ice, and glare make it hard to see. The extended wear of night vision goggles, protective masks, or laser protective lenses causes

stress. Intense noise not only causes stress by itself, but it further isolates the soldier from human contact and interferes with situational awareness. To the company level leaders situational awareness means being able to answer certain questions:

1. Where am I (in respect to the urban area or my assigned sector)?
2. Where are my soldiers? What is their current status/activity?
3. Where are friendlies (adjacent and supporting units)? What is their current status/activity?
4. Where is the enemy? What are the enemy's capabilities? (Department of the Army, 2002)

Clearly, auditory cues, especially in limited visibility situations requiring enhanced situational awareness, play a vital role in leaders and soldiers being able to answer these questions (Department of the Army, 2002).

Successful combat operations in urban areas depend on the proper employment of the rifle squad. Each member must be skilled in moving, entering buildings, clearing rooms, employing hand grenades, selecting and using fighting positions, navigating in urban areas, and camouflage (Department of the Army, 2002). The main emphasis of this study will be on the room clearing phase of Urban Operations.

There are two different techniques for conducting a room clearing operation. The High Intensity technique, in which a fragmentation or concussion grenade is thrown into a room before the US forces enter, and the Precision Technique. The primary consideration in determining which technique to use is whether or not there is a possibility of noncombatants being present in the room. Precision clearing techniques do not replace other techniques currently being used to clear buildings and rooms during high-intensity combat. Precision room clearing techniques are used when the tactical situation calls for room-by-room clearing of a relatively intact building in which enemy combatants and noncombatants may be intermixed. They involve increased risk in order to clear a building methodically, rather than using overwhelming firepower to eliminate or neutralize all its inhabitants (Department of the Army, 2002).

From a conceptual standpoint, standard high-intensity room clearing drills can be thought of as a deliberate attack. The task is to seize control of the room with the purpose being the neutralization of the enemy in the room. The fragmentation and or

concussion grenades can be thought of as the preparatory fires used before the assault. As in a deliberate attack against any objective, the assaulting elements move into position using covered and concealed routes. The preparatory fires (fragmentation and or concussion grenades) are initiated when soldiers are as close to the objective as they can get without being injured by the fires. The assault element follows the preparatory fires onto the objective as closely as possible. A rapid, violent assault overwhelms and destroys the enemy force and seizes the objective (Department of the Army, 2002).

Compared to the deliberate attack represented by high-intensity room clearing techniques, precision room clearing techniques are more conceptually like a reconnaissance in force or perhaps an infiltration attack. During a reconnaissance in force, the friendly unit seeks to determine the enemy's locations, dispositions, strength, and intentions. Once the enemy is located, the friendly force is fully prepared to engage and destroy it, especially if surprise is achieved. The friendly force retains the options of not employing preparatory fires (fragmentation and or concussion grenades) if they are not called for (the enemy is not in the room) or if they are inappropriate (there are noncombatants present also). The attacking unit may choose to create a diversion (use a stun grenade) to momentarily distract the defender while they enter and seize the be planned and executed with care. Units must train, practice, and rehearse precision room clearing techniques until each fire team and squad operates smoothly. Each unit member must understand the principles of precision room clearing: surprise, speed, and controlled violence of action (Department of the Army, 2002).

Surprise is the key to a successful assault at close quarters. The fire team or squad clearing the room must achieve surprise, if only for seconds, by deceiving, distracting, or startling the enemy. Sometimes stun grenades may be used to achieve surprise. These are more effective against a nonalert, poorly trained enemy than against alert, well-trained soldiers (Department of the Army, 2002).

Speed provides a measure of security to the clearing unit. It allows soldiers to use the first few vital seconds provided by surprise to their maximum advantage. In precision room clearing, speed is not how fast you enter the room, rather it's how fast the threat is eliminated and the room is cleared (Department of the Army, 2002).

Controlled violence of action eliminates or neutralizes the enemy while giving him the least chance of inflicting friendly casualties. It is not limited to the application of firepower only, but also involves a soldier mind-set of complete domination. Each of the principles of precision room clearing has a synergistic relationship to the others. Controlled violence coupled with speed increases surprise. Hence, successful surprise allows increased speed (Department of the Army, 2002).

In order to examine the auditory cues associated with the room clearing task, one must first gain an understanding of the procedures used to actually conduct the task. MAJ Warren Aronson has recently completed a Cognitive Task Analysis of the entire room clearing task that describes, in detail, the steps used to complete a room clearing operation (Aronson, 2002). For a detailed examination of the auditory requirements, an overview of these procedures and fundamentals can be used.

The eleven fundamentals of precision room clearing address actions soldiers take while moving along confined corridors to the room to be cleared, while preparing to enter the room, during room entry and target engagement, and after contact. Team members:

1. Move tactically and silently while securing the corridors to the room to be cleared.
2. Carry only the minimum amount of equipment. (Rucksacks and loose items carried by soldiers tire them, slow their pace, and cause noise.)
3. Arrive undetected at the entry to the room in the correct order of entrance, prepared to enter on a single command.
4. Enter quickly and dominate the room. Move immediately to positions that allow complete control of the room and provide unobstructed fields of fire.
5. Eliminate all enemy in the room by fast, accurate, and discriminating fires.
6. Gain and maintain immediate control of the situation and all personnel in the room.
7. Confirm whether enemy casualties are wounded or dead. Disarm, segregate, and treat the wounded. Search all enemy casualties.
8. Perform a cursory search of the room. Determine if a detailed search is required.
9. Evacuate all wounded and any friendly dead.

10. Mark the room as cleared using a simple, clearly identifiable marking in accordance with the unit SOP.
11. Maintain security and be prepared to react to more enemy contact at any moment. Do not neglect rear security (Department of the Army, 2002).

The following is a list of required actions for performing the task of clearing a room:

1. The squad leader designates the assault team and identifies the location of the entry point for them.
2. The squad leader positions the follow-on assault team to provide overwatch and supporting fires for the initial assault team.
3. Assault team members move as close to the entry point as possible, using available cover and concealment.
    a. If an explosive breach or a ballistic breach is to be performed by a supporting element, the assault team remains in a covered position until the breach is made. They may provide overwatch and fire support for the breaching element if necessary.
    b. All team members must signal one another that they are ready before the team moves to the entry point.
    c. Team members avoid the use of verbal signals, which may alert the enemy and remove the element of surprise.
    d. Assault team members must move quickly from the covered position to the entry point, minimizing the time they are exposed to enemy fire.
4. The assault team enters through the breach. Unless a grenade is being thrown prior to entry, the team should avoid stopping outside the point of entry.
    a. The number 2 man may throw a grenade of some type (fragmentation, concussion, stun) into the room before entry.
    b. The use of grenades should be consistent with the ROE and building structure. The grenade should be cooked off before being thrown, if applicable to the type of grenade used.
    c. If stealth is not a factor, the thrower should sound off with a verbal indication that a grenade of some type is being thrown (“frag out,”

"concussion out," "stun out"). If stealth is a factor, only visual signals are given as the grenade is thrown.

5. On the signal to go, or immediately after the grenade detonates, the assault team moves through the entry point and quickly takes up positions inside the room that allow it to completely dominate the room and eliminate the threat. Unless restricted or impeded, team members stop movement only after they have cleared the door and reached their designated point of domination (Department of the Army, 2002).

The first man enters the room and eliminates the immediate threat. He has the option of going left or right, normally moving along the path of least resistance to one of two corners. The direction each man moves in should not be preplanned unless the exact room layout is known. Each man should go in a direction opposite the man in front of him. Every team member must know the sectors and duties of each position. On order, any member of the assault team may move deeper into the room overwatched by the other team members. Once the room is cleared, the team leader signals to the squad leader that the room has been cleared (Department of the Army, 2002).

When conducting precision clearing, soldiers are very close to each other as they engage targets. The high volume of noise makes communications extremely difficult. The command and control techniques used during precision combat must consist of terms and actions that soldiers are familiar with and to which they know how to respond. The use of verbal commands and signals within the assault element are extremely important. The soldier must always let others in the assault element know where he is and what he is doing. As an example, terms similar to the ones listed in Table 1 should be a part of each soldier's vocabulary IAW unit SOP (Department of the Army, 2002). Each unit with a room clearing mission will have its own SOP of verbal commands. These commands are practiced and rehearsed during each training exercise that the unit conducts (Aronson 2002). Table 1 shows a full representation of the types of commands that units need to incorporate into their verbal command SOPs.

"STATUS!"	Signal by an element leader that requires all members to report whether their sectors are clear and if they are prepared to continue the mission.
"CLEAR!"	Signal given by individuals to report their sector is clear.
"UP!"	Signal given by individuals to report they are ready to continue the mission (weapon loaded, equipment accounted for).
"ROOM CLEAR!"	Signal from team leader to team members, squad leader, and follow-on teams that the room is secure and cleared.
"COMING OUT!"	Signal given by an individual or team that they are about to exit a room.
"COME OUT!"	Reply given by security element or follow-on team that it is safe to exit the room.
"COMING IN!"	Signal given by an individual who is about to enter an occupied room.
"COME IN!"	Reply given by an occupant of a room stating it is safe to enter.
"COMING UP (DOWN)!"	Signal given by an individual or team that is about to ascend or descend a stairway.
"COME UP (DOWN)!"	Reply given by security element that it is safe to ascend or descend a stairway.
"MAN DOWN!"	Signal given when an individual has been wounded or injured and cannot continue his mission.
"SHORT ROOM!"	Signal given by either the number 1 man or the number 2 man to indicate a small room, and that all team members should not enter.
"GRENADE!"	A command given by any soldier, when an enemy grenade has been thrown. All soldiers need to take immediate actions. Although difficult, the soldier should identify the location of the grenade, if possible.
"GO LONG!"	A command given by one member of the team to tell another team member to take up security farther into the room or farther down a hallway.
"GUN DOWN"	A signal given when an individual's weapon has malfunctioned and is being corrected.
"GUN UP"	A signal given when an individual has corrected a malfunction and is ready for action.
"RELOADING"	A signal given when an individual is reloading any weapon system. This signal is followed by "GUN UP" when ready.

Table 1. Typical Verbal Commands

The use of loud verbal commands may reveal to the enemy the location and immediate intent of friendly forces. Although code words may be substituted, they can be heard and used by enemy forces if friendly forces use them too loudly (Department of the Army, 2002).

Urban areas provide unique target acquisition challenges to units. Buildings mask movement and the effects of direct and indirect fires. The rubble from destroyed

buildings, along with the buildings themselves, provides cover and concealment for attackers and defenders, making target acquisition difficult. Urban areas often favor the defender's ability to acquire targets so this makes offensive target acquisition extremely important, since the side that fires first may win the engagement. Target acquisition must be continuous, whether a unit or soldier is halted or moving. The six steps of target acquisition, search, detection, location, identification, classification, and confirmation are no different in an urban environment than anywhere else but are usually performed at a much faster pace (Department of the Army, 2002).

Using all senses during the search step enhances the detection capabilities of all soldiers on the urban battlefield. Soldiers searching the urban battlefield for targets should employ target acquisition devices. Observation duties must be clearly given to squad members to ensure 360 degrees and three-dimensional security as they move. This security continues at the halt. Soldiers soon recognize the sights, smells, sounds and so forth, associated with their urban battlefield and can soon distinguish targets. Stealth should be used when moving in urban areas since there are often short distances between attackers and defenders. Hand and arm signals should be used until contact is made. The unit should stop periodically to look and listen. Routes should be carefully chosen so that buildings and piles of rubble can be used to mask the unit's movement. Personnel, weapons, and vehicles have distinguishing signatures. Soldiers must recognize signatures so they can acquire and identify targets. This is extremely important in the urban battlefield, where one or more senses can be degraded. For example, soldiers operating in an urban area where smoke is used as an obscurant will have their sense of sight degraded, since they may not be able to see through the smoke with the naked eye. Their sense of smell and breathing is also affected. Running engines, vehicles, and soldiers moving through rubble-covered streets can be heard for great distances. Vehicles driven in urban areas produce more noise than those moving through open terrain. Soldiers moving through rubble on a street or in the halls of a damaged building create more noise than in a wooded area. Sounds and smells can aid in acquiring targets at night since they transmit better in the cooler, damper night air. Dust and noise created by the firing of some weapons such as a tank main gun can be seen and smelled. Voices can often be heard at long distances, with the sound reflecting off of structures. As a minimum,

identification must determine if a potential target is friend, foe, or, a noncombatant. Correct identification is the key to preventing fratricide. To determine an appropriate method of dealing with a target, the soldier must determine the danger it represents. It requires quick decisions as targets are observed and occurs virtually simultaneously with identification. Situational awareness is vitally important. Multiple targets must be classified from most dangerous to least dangerous and engaged starting with the most dangerous. The rapid verification of the initial identification and classification of the target is the final step of target acquisition. Identification, classification, and confirmation are done simultaneously (Department of the Army, 2002).

MOUT and room clearing operations present many additional unique challenges in regard to auditory cues for soldiers. Command, control, communications, and the limited visibility afforded to soldiers all have auditory aspects that require examination. The first phase of the attack should be conducted when visibility is poor. Troops can exploit poor visibility to cross open areas, gain access to rooftops, infiltrate enemy areas, and gain a foothold. If the attack must be made when visibility is good, units should consider using smoke to conceal movement. Commanders and leaders must consider the effect that city lights, fires, and background illumination have on night vision devices. These elements may limit the effectiveness of night vision goggles (NVGs) and make thermal imagery identification difficult. Control of the urban battlefield is difficult. In urban areas, radio communications are often less effective than field telephones and messengers. Units often fight without continuous communications. Pyrotechnic signals are hard to see because of buildings and smoke. The high noise level of battles within and around buildings degrades voice alerts. Voice communication can also signal the unit's intention and location to the enemy. Radio communications in urban areas pose special problems to tactical units. Communications equipment may not function properly because of the massive construction of buildings and the environment. In addition to the physical blockage of line of sight transmissions, there is also the interference from commercial power lines, absorption into structures and the presence of large quantities of metal in structures. Also, the noise of urban combat is much louder than in other areas, making sound or verbal signals difficult to hear. Urban operations require centralized planning and decentralized execution. Therefore, effective vertical and horizontal

communications are critical. Leaders must trust their subordinates' initiative and skill, which can only occur through training. The state of a unit's training and cohesion are vital, decisive factors in the execution of operations in urban areas. Visual signals may also be used but are often not effective because of the screening effects of buildings, walls, and so forth. Signals must be planned, widely disseminated, and understood by all assigned, attached, or OPCON units. Increased noise makes the effective use of sound signals difficult. Verbal signals may also reveal the unit's location and intent to the enemy (Department of the Army, 2002).

B. KNOWLEDGE ACQUISITION

There are many experts that possess a great store of knowledge in the subject domain of MOUT room clearing and that have actual experience using the related auditory cues necessary for a successful room clearing operation. In order for an experimenter who is not a domain expert to use that knowledge, however, a method of acquiring and representing domain specific knowledge must be developed and utilized. Expert knowledge may be obtained from many different sources: textbooks, reports, data bases, case studies, empirical data, and personal expertise. The primary source, however, is the domain expert, the individual with expertise in the field of interest. This knowledge must usually be obtained through direct interaction with the expert. The actual elicitation of knowledge is highly problematic because experts possess much information that is cognitively complex, pragmatic, and tacitly formulated (Patterson, 1990).

Any expert has knowledge that is explicit and objective, as well as knowledge that is more implicitly formulated (Hawkins, 1983). The later is usually very difficult for experts to articulate (Broadbent, Fitzgerald, and Broadbent, 1986). It is important to recognize that a domain expert will possess knowledge of several different kinds (Berry, 1987). Each type of knowledge demands a technique that can most effectively capture it. The technique must transform this knowledge to a representation suitable for the inference strategy used in the problem solving technique. Rather than use a single knowledge acquisition technique, several techniques should be employed, with each matched to a different kind of knowledge (Gammack and Young, 1985).

The nature of the task is an important feature that should be explored when the components of an expert's knowledge are investigated. The nature of the task is salient in that it determines the possible strategies an expert uses to complete or solve a task (Hogarth, 1974). When the particular problem solving task is isolated and identified, the type of knowledge necessary to solve that problem, independent of any particular implementation, should be analyzed and described. This enables the examiner to decompose the expert's compiled knowledge and to identify discrete tasks, types of knowledge being processed, and the relationships among the data, facts, and procedures (McGraw and Riner, 1987).

Selection of the appropriate knowledge acquisition technique requires that the examiner recognize the type of knowledge under investigation. Major problems associated with expert knowledge investigation include recognition and analysis of domain knowledge and selection of an appropriate knowledge acquisition technique. One widely accepted scheme classifies knowledge into four basic types: procedural, declarative, semantic, and episodic (McGraw and Riner, 1987). Procedural knowledge includes the skills that an individual knows. It may involve an automatic response to a stimulus, and can be reactionary in nature. Such skills are deeply ingrained and linked sequentially, one step serving as the completing the next. This knowledge is implicit and highly compiled so that an expert will have great difficulty in both identifying and verbalizing it, and is therefore of primary interest to knowledge examiners (McGraw and Reiner, 1987). When individuals master increasingly more knowledge to carry out a task efficiently, they also lose awareness of what they know. This has been called the "paradox of expertise" (Johnson, 1983). Procedural knowledge is not necessarily motor in nature. This type of knowledge may also include that which is gained from implicit learning or an unconscious process such as socialization, perception, and the rules of complex games (Gammack and Young, 1985). Declarative knowledge represents surface level information that experts can verbalize. The primary difference between this and procedural knowledge is the ability to verbalize or express it. Declarative knowledge is what the expert is conscious of knowing. Semantic knowledge represents one of the two theoretical types of long term memory. It reflects cognitive structure, organization, and representation. As a result, it will be difficult for experts to express. This type of

knowledge includes memories for vocabulary, concepts, facts, definitions, and relationships among facts. Episodic knowledge is autobiographical, experience-oriented information that the expert has grouped or chunked by episodes and is the second theoretical type of long term memory. It consists of information organized by time and place of occurrence, and often may be described in terms of perceptual characteristics. This is highly compiled information and is one of the most difficult types of knowledge to extract and dissect. Since the knowledge is chunked, the expert may or may not be aware of the separate knowledge entities and decision making processes used to complete the task (McGraw and Reiner, 1987).

Identification of the application task characteristics is important because this will influence selection of the knowledge acquisition tool and the strategies to be applied in building and refining the knowledge base. The characteristics of the task affect the manner in which an expert will store and access task-critical knowledge, and will determine the problem-solving strategy. Expert knowledge is task centered, so analyzing the processing states and considerations an expert applies when performing a task or making a decision is key to attaining an initial understanding of the domain (Riesbeck, 1984).

Several methods have been developed for knowledge acquisition, and no single technique is usually used to the exclusion of others. Sometimes a combination approach may be used while in other circumstances different techniques may be appropriate to different stages of the acquisition process. When selecting a specific technique, a knowledge examiner should identify and isolate the problem-solving task to be simulated. Then the type of knowledge necessary to solve that problem should be described and analyzed, independent of any particular implementation (Kidd, 1987).

The interview is the most common technique for the elicitation of domain knowledge from an expert (Gammack and Young, 1985). Interviews quickly allow the knowledge examiner to grasp important domain concepts and vocabulary. The expert may reveal the objects he thinks about, how they are related, the judgmental processes used in solving a problem, and some inference rules. Most interviews are conducted in an unstructured form and will seldom provide complete or well organized descriptions of cognitive processes (Olson and Rueter, 1987). At this point the knowledge examiner

should switch to focused or structured interviews that involve careful preplanning of the questions and their order. This represents a more goal oriented approach that may uncover additional data on factual knowledge, types of problems, functions of expertise, and explanations (Kidd, 1987).

C. STRUCTURED INTERVIEWING TECHNIQUES

A structured interview will be developed and administered to Subject Mater Experts (SMEs) in the MOUT room clearing domain in order to obtain those auditory cues deemed most important for inclusion in the room clearing VE. Structured interviews are often used in conjunction with a design that employs statistical sampling. This combination provides data that can be used to make projections about the entire population from which the sample was drawn. The steps in the evaluation design process are defining the questions that dictate the objectives of the study, selecting the method of collecting the information, and preparing an analysis plan for using the collected information to answer the questions (U.S. General Accounting Office, 1991).

Data-collection instruments (DCIs) are used on assignments that require the same or uniform information on numerous cases. A DCI is a document containing questions presented in a systemic, highly precise fashion. Its purpose is to enable the evaluator to obtain uniform data that can be compared, summed, and, if it is quantitative, subjected to additional statistical analysis. An interview that uses a DCI to gather data, either by telephone or face to face, is a structured interview, one in which evaluators ask the same questions of numerous individuals in a precise manner, offering each interviewee the same set of possible answers (U.S. General Accounting Office, 1991).

Designing a structured interview requires more than just writing down a set of questions to be asked. One must first examine the process by which the interview questions are identified, developed, and selected; then describe standard procedures for composing and formatting the questions. These procedures aim to ensure that the data collected are reliable and valid and to facilitate trouble-free editing and analysis of data, while keeping the burden on the interviewee to a minimum (U.S. General Accounting Office, 1991).

The first step is to formulate the broad, overall questions to be answered by the evaluation. Why is the study being done? What do we hope to be able to say or prove?

The type of question asked will dictate the evaluation strategy. After the broad overall questions are developed, they must be translated into measurable elements in the form of hypotheses or questions. Next, the target population must be identified. The target population is the source level (individuals, groups, or organizations) at which the information is to be gathered. Then develop a pool of questions that attempt to measure the variables under consideration. From the pool of questions, the most useful or appropriate are chosen. In order for questions to be deemed appropriate, they must be relevant to the study, directed to the proper persons, and easily answered. Considerations on the type or format of question to use include how the question is delivered or presented, what the interviewee is asked, and available response alternatives. Among the types of questions asked are open-ended, fill-in-the-blank, binary-choice, and scaled-response. The open-ended question provides no structure for the answer, allowing the interviewee to discuss what he or she wishes, not necessarily what the interviewer wants to know. Fill-in-the-blank questions have a simple answer, usually in the form of a name, frequency, or amount. Binary-choice questions are the typical yes-no, true-false type of questions, a good format for obtaining factual information, but generally not opinions or feelings. In the scaled-response question, you read or show to the interviewee a scale or list of alternative responses that increase or decrease in intensity in an ordered fashion. The number of cues (scaled responses) for scaled-response questions depends on the type of interviewee and type of analysis expected. There is generally a physical limit to the number of cues to which an interviewee can react, probably around seven. In any interview, the order in which the questions are presented is important. Early questions, which set the tone for the collection procedure and can influence responses to later questions, also help you get to know the interviewee and to establish the rapport essential to a successful interview. Further methods of composing good interview questions and forestalling problems with comprehension or bias include considering the appropriateness and level of language used in the interview, the effects of qualifying language, and the importance of clarity. Whether interviewing language is appropriate or inappropriate may relate to what is said, how it is said, or when it is said. When composing interview questions, one should consider the level of the language used. Seek to communicate at the level the interviewee understands and to create a verbal setting that is conductive to

serious data gathering yet one in which the interviewee is comfortable. After composing an interview question, it may be necessary to use an adjective, qualifying phrase, or time specified to make the item complete or to give the interviewee sufficient or complete information. The style in which a question is couched can effect its clarity of communication. Style issues include such matters as question length, complexity, clutter, double negatives, extreme language, and defining terms. A question is biased when it causes interviewees to answer in a way that does not reflect their true positions on an issue. An interviewer may or may not be aware of the bias. Bias can appear in the stem (or statement) portion of the question or in the response-alternative portion. Bias may also result when a question carries an implied answer, choices of answer are unequal, "loaded" words are used, or a scaled question is unbalanced (U.S. General Accounting Office, 1991).

Pretesting and expert review constitute what could be the least appreciated phase in the development of a structured interview, but these are perhaps the most important developmental steps. They constitute an iterative process that uses continuing input from evaluators and technical specialists to derive the final product. In pretesting, we test the DCI with respondents drawn from the universe of people who will eventually be considered for the study interviews to predict how well the DCI will work during actual data collection. The pretest seeks to determine if the right questions are being asked, if the content of each question is relevant, and if the wording and procedures used in the interview are adequate. The initial steps of a pretest are the same as for actual data collection. Problems with the DCI or procedures often become evident immediately and may be dealt with then, so that the interview may proceed. Ideally, it is desirable to run through the entire interview without getting sidetracked. This way, you can examine the flow of the interview and estimate the total time needed to complete it. After the pretest, identify any problems that the interviewer has in asking the questions or the interviewees have in answering the questions. The expert review is an attempt to seek outside help on our approach to the structured interview. It helps to determine if the questions being asked and the manner in which they are asked are adequate to answer the overall question posed in the evaluation. By obtaining expert help, we avoid potential problems after data collection is complete. Persons providing expert review are not acting as interviewees.

They do not answer the questions but instead provide a critique (U.S. General Accounting Office, 1991).

Prior to conducting a structured interview, interviewers need to be trained. Although they are not subject matter experts in the subject domain, they need to have at least a cursory understanding of the overall principles involved and any domain specific language that the actual SME will use. Interviewers also need to know the purpose of the evaluation and the procedures for conducting the interviews. At a minimum, interviewers need to know what an adequate answer to each question is, how to ask the questions correctly, not to omit questions they think are answered by other questions, and how to avoid introducing bias (U.S. General Accounting Office, 1991).

Each participant in the interview (interviewer and interviewee) has a role to perform and a set of behaviors that assist in the performance. Because the role and behaviors of each one influence the conduct of the interview, they affect the conduct of the interview. The interviewer's role and behaviors can be prescribed and acquired through training, while the interviewee's role and behaviors must be observed by the interviewer. The role of the interviewer is to ask the questions, while that of the interviewee is to respond with answers. The interviewer must perform at least eight major tasks:

1. Develop rapport with the interviewee and show interest.
2. Give the interviewee a reason to participate.
3. Elicit responsiveness from the interviewee.
4. Ask questions in a prescribed order and manner.
5. Ensure understanding.
6. Ensure nonbias.
7. Obtain sufficient answers.
8. Show sensitivity to the interviewee's burden (U.S. General Accounting Office, 1991).

The purpose of all the work put into designing, pretesting, revising, obtaining expert review, and finally administering the structured interview is to obtain data that, when properly analyzed, will answer the evaluation or audit question. The analysis to be

done will be determined to a great degree by the objectives that have been established for the structured interview (U.S. General Accounting Office, 1991).

D. CRITICAL DECISION METHOD

Since the purpose of this study is to examine the auditory cues associated with a MOUT room clearing operation, the structured interview administered to domain experts needs to be prepared using a method that will reveal those associated auditory cues. One such method that can generate an inventory of critical cues is the Critical Decision Method (CDM) (Klein, Calderwood, & MacGregor, 1989). The CDM is a retrospective interview strategy that applies a set of cognitive probes to actual nonroutine incidents that required expert judgment or decisionmaking (Klein, Calderwood, & MacGregor, 1989). It relies on interviews with proficient decisionmakers to examine recent cases of interest and determine the basis for situation assessment and decisionmaking during those nonroutine incidents (Klein, Calderwood, & MacGregor, 1989).

A common element that exists in all efforts to improve human performance is a specification of the bases of skill performance that will enable task performance to be enhanced through training, aiding, or automation. One approach for improving the overall level of human performance in a task is to understand how proficient individuals perform that task. By studying in detail the general knowledge, specific information, and reasoning processes an expert uses, a model of the task can be constructed that exhibits some of the properties of the expert being modeled (Klein, Calderwood, & MacGregor, 1989).

It would be a mistake to select a knowledge elicitation strategy without first developing a perspective on expert performance. Any technique will highlight some aspects of expertise and de-emphasize others. To interpret the results of a knowledge elicitation effort, it is necessary to appreciate the various aspects of proficient performance. The knowledge elicitor needs to understand both what is being captured and what is being missed. One class of knowledge necessary for expertise is explicit and objective knowledge. This class includes factual knowledge, if/then rules, and analytical procedures. A second component of expertise, contextual knowledge, is described as tacit knowledge, since it is resistant to being articulated. Contextual knowledge is viewed as the background of practices enabling experts to articulate if/then rules and

apply analytical procedures. Judgments of typicality are tacit since you don't have to analyze a situation to determine experienced similar cases in the past. A third aspect of expertise involves perceptual learning and the development of perceptual-motor feel. As skills are mastered, finer discriminations are made and tools come to be manipulated automatically. It is essential that knowledge elicitation methods include some means of representing the contribution made by tacit knowledge and by perceptual learning. If the knowledge elicitation method is insensitive to tacit knowledge, then it is easy to draw the mistaken conclusion that expert knowledge is sufficient for performing a task well (Klein, Calderwood, & MacGregor, 1989).

The CDM is a retrospective interview strategy that applies a set of cognitive probes to actual nonroutine incidents that required expert judgment or decisionmaking. Once the incident is selected, the interviewer asks for a brief description. Then a semistructured format is used to probe different aspects of the subject task. The CDM offers some specific features that distinguish it from other knowledge elicitation strategies. The CDM, like all critical incident techniques, focuses on nonroutine cases. Incidents that are nonroutine or difficult are usually the richest source of data about the capabilities of highly skilled personnel. In a critical decision interview, questions always refer to a specifically recalled incident. We usually obtain more specific and useful information when we probe concrete and nonroutine events than when we ask about general rules and procedures. Probing in the CDM is not limited to responses that can be objectively anchored and verified. Questions sometimes require the decisionmakers to reflect on their own strategies and bases for decisions. Although specific questions are asked for each decision point, the order and wording can still follow the natural flow of a dialogue. Because interviewers have "heard the whole story" before probing begins, they are in a better position to adapt the timing and wording of questions to the specific case (Klein, Calderwood, & MacGregor, 1989).

The procedures adopted for the critical decision interviews represent solutions to meeting the overall goals and practical considerations of a study. The basic procedures can be summarized in five steps: (Klein, Calderwood, & MacGregor, 1989)

Select the incident. Incidents are selected that can illustrate nonroutine aspects of a domain. The goal is to probe for components that go beyond the general knowledge

and procedures that enable a competent individual to perform routine tasks; we want to study those components that might discriminate the true expert. We ask the decisionmaker to select an incident that was challenging and that, in his or her decisionmaking, might have differed from someone with less experience (Klein, Calderwood, & MacGregor, 1989).

Obtain unstructured incident account. The interviewee is asked to describe the entire incident. This account proceeds without interruption by the interviewer, except for minor points of clarification. The procedure accomplishes several goals. First, it creates a context for understanding on the part of the interviewer. Second, the account serves to activate the interviewee's memory of the event as a context for questioning. In addition, the procedure helps to achieve a high level of cooperation from the interviewee by establishing the interviewer as a listener rather than an interrogator (Klein, Calderwood, & MacGregor, 1989).

Construct incident timeline. After the incident is related, the interviewer proceeds to reconstruct the account in the form of a timeline that establishes the sequence and duration of each event reported by the interviewee. The timeline serves to establish a shared awareness of the facts of the event from the interviewee's perspective. Inconsistencies in the account may be detected and corrected on the basis of the timeline, and missing facts filled in (Klein, Calderwood, & MacGregor, 1989).

Identify decision points. During the timeline construction, specific decisions are identified for further probing. A decision point is probed if the interviewee would agree that other reasonable courses of action were possible or that another expert (perhaps one with less or greater expertise) might have chosen differently (Klein, Calderwood, & MacGregor, 1989).

Probe decision points. Different studies use different probes, depending on the objectives of the project. Questions to elicit the details of cue usage are almost always asked first as part of the timeline construction, and represent the current information that is likely to have been heeded at each event time. Prior knowledge is also probed. Probes about opinions are asked for each decision, both those that were actually deliberated and those that existed only hypothetically (Klein, Calderwood, & MacGregor, 1989).

Most interview sessions are planned to last for about two hours, but length can be adjusted to meet the complexity and time constraints of a given application. It is usually valuable to allow the interviewee to draw a diagram during the recounting of an incident and in response to specific probes. For many individuals the diagram serves as a necessary memory aid in reconstructing the key features of the incident. It also provides a common source of reference in communicating the participant's perspective to the interviewer (Klein, Calderwood, & MacGregor, 1989).

The needs of the specific research goal define the nature of the possible products derived from the CDM interview. One potential product is the Critical Cue Inventory (CCI). The CCI is a collection of all of the information and perceptual cues that are pinpointed in the protocols. Many of the probes in the critical decision interview are directed at gaining specific cues that were used in formulating a situation assessment or considering options. Many of these cues are not spontaneously mentioned by decisionmakers and do not result from asking very general questions. This is why cognitive probes are needed (Klein, Calderwood, & MacGregor, 1989).

In the end, this entire process should result in a listing of auditory cues associated with the room clearing task as well as a method of prioritizing those cues for inclusion in a virtual environment representation of the task.

III. SUBJECT MATTER EXPERT INTERVIEW

In order to gain insight into the auditory cues used in a room clearing operation, the first step was to recruit subject matter experts who were willing to be interviewed using the Critical Decision Method. The method used to recruit the SMEs was to send a mass e-mail to all of the current Naval Postgraduate School (NPS) students who fell into one of the following four categories:

1. U.S. Army Special Operations officers
2. U.S. Army Infantry officers
3. U.S. Navy SEALs
4. U.S. Marines.

A total of 15 students volunteered and the field was narrowed down to eight SMEs based on the amount of experience that they actually had in room clearing operations. The final eight SMEs consisted of one U.S. Army Special Operations officer, one U.S. Army Infantry officer, one U.S. Navy SEAL, and five officers in the U.S. Marines. The average time in service of these eight SMEs was over 12 years.

To conduct the interviews, individual meetings were held with each SME in a small 2-man study room at the Dudley Knox Library on the NPS campus. After a brief introduction, participants were told that the purpose of the interview was to obtain a detailed list of all the auditory cues used during an actual room clearing operation. Each SME was told that the interview results would be used to develop guidelines for a realistic virtual representation of the room clearing task and that the interviews were constructed using the Critical Decision Method of knowledge elicitation, which would result in a Critical Cue Inventory of auditory cues. The SMEs were given a description of the five steps of the CDM that would be used: 1) Select the incident. 2) Obtain unstructured incident account. 3) Construct incident timeline. 4) Identify decision points/phases. 5) Probe decision points/phases. Finally, it was explained that the last step would be to rank order the auditory cues for each phase of the operation by importance.

At this point in the procedures, all eight of the SMEs indicated that they did not believe they would be able to recall what auditory cues they had used during their room

clearing operations. They stated that the task was primarily a visual task, that there were too many extremely loud noises to be able to differentiate between individual sounds, and that the excitement and adrenalin caused by conducting the task did not allow them to remember the auditory aspects of the task. All eight of the SMEs were convinced to continue by explaining to them that the CDM procedures would assist them in focusing their memory and attention on the auditory cues they had used.

The first interview was used as a pretest of the interview procedures and questions that had been developed. The only change to the interview that resulted from the pretest was to rename the phases of the operation that would be used for in-depth probing into more easily understandable and distinguishable parts.

A. SELECT THE INCIDENT

All of the SMEs had a great deal of experience in different types of room clearing operations. To assist them in determining which particular incident to select for the interview, the SMEs were given a general description of some of the characteristics that they should use to select the incident. They were asked to bring to mind an occasion when they conducted a room clearing operation, if possible, when they used the Precision room clearing technique rather than the High Intensity technique. They were told that this should be an operation that offered minimal information prior to its execution; one in which there was the possibility of having noncombatants in the room to be cleared, the number and location of enemy forces was unknown, and if possible, one in which they were not familiar with the content and exact layout of the room to be cleared. They were asked to select an operation that was a challenge, that offered numerous auditory cues, and one in which their decisions and actions lead to a successful outcome.

All of the SMEs were able to recall an actual room clearing operation that met these guidelines.

B. OBTAIN UNSTRUCTURED INCIDENT ACCOUNT

After the SMEs decided on a particular incident, they were asked to tell the story of that room clearing operation. They were told to give a brief description of the background leading to the mission and then explain everything they remembered from the time that they initiated movement until the end of the operation. They were told that the interviewer would listen and take a few notes and would only interrupt if clarification

was needed. It was explained that it might help to draw a map or sketch as they related the incident.

All of the SMEs drew a map of the room and surrounding area relating to their operation. They went into extreme detail, relating their every action and thought throughout the process. The interviewer listened to the accounts and tried to obtain as great an understanding as possible as to the sequence of events and overall situation, as well as the tactics, techniques, and procedures used.

C. CONSTRUCT INCIDENT TIMELINE

After the SME was done relating his room clearing incident, the interviewer constructed a timeline of the operation using the information provided. This was done to ensure that the interviewer really did understand the overall situation and to demonstrate that level of understanding to the SME. The SMEs were asked to tell the interviewer if something was missed or if the sequence or duration of any event was misunderstood.

D. IDENTIFY DECISION POINTS/PHASES

Once the SME and interviewer agreed that the timeline was accurate, it was divided into four separate phases:

1. Plan, prep, and movement to breach site.
2. Creation of breach.
3. Clearing of the room.
4. Disengagement

These phases provided the structure for asking specific probing questions aimed at determining the auditory cues involved in the task.

E. PROBE DECISION POINTS/PHASES

At this point, the process had provided a timeline of a specific mission broken down into four distinct phases. The SMEs were then asked a series of 13 questions about the auditory cues associated with each phase and how those auditory cues were used by the SME. The questions keyed on the auditory aspects of essential pieces of information that are critical for successfully completing a room clearing operation (See Appendix A).

F. RANK-ORDER AUDITORY CUES

The final step in the interview process was to have the SME consider all of the auditory cues he had mentioned during the probing questions and to prioritize those cues

according to the impact that they had on his ability to successfully complete each phase of the operation. The SMEs were reminded that the importance of an auditory cue could come from the fact that he was or was not able to hear something, or it could come from the fact that the enemy was or was not able to hear something. The SMEs prioritized each auditory cue for each phase of the operation.

G. INTERVIEW RESULTS

Each interview lasted between 2 and 3 1/2 hours and resulted in a great deal of specific information and expert insight into room clearing auditory cues. Before the interviews began, all of the SMEs were skeptical about how much useful information that they would be able to recall relating to the auditory aspect of the task. At the end of the process, however, every one of the SMEs commented on how surprised they were at the level of detail they were able to reach regarding the presence and relative importance of the associated auditory cues. The structured interview built on the framework of the Critical Decision Method helped them to remember and focus on auditory cues that they had never considered before.

At this point, the interview process had provided a complete list of auditory cues used by each SME during their particular room clearing operation, but it was still necessary to consolidate the results across all eight experts. In order to obtain overall results from each of the individual interviews, a weighting method was applied to each of the SME's rank-ordered results. The Auditory Critical Cue Inventory depicted in Table 2 awarded a specific auditory cue an overall score of 14 points for each time that a SME ranked that cue as the most important cue for a specific phase of the operation. A score of 13 points was given for each number 2 ranking, 12 points for each number 3 ranking, and so on. No points were given if the SME did not mention a particular auditory cue.

The Auditory Critical Cue Inventory shows the final rank of each auditory cue by phase, the rank that each individual SME gave the auditory cue, and the overall score that each cue earned as a result of the weighting process.

RANK						SME				SCORE
	Phase 1: Movement to Breach Site	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1	Radio comms with higher	2	1	2	1	1	3	3		92
2	Stealth/Sound of own unit	3	2	3	3		4	1	3	86
3	Enemy voice/activity	1	4	4			1	5	2	73
4	Verbal comms within team	4			2	2	2		1	64
5	Background noise		3		4	3	5	4		56
6	Enemy weapons			1					4	25
7	Radio comms within team							2		13
8	Supporting unit weapons			5						10
	Phase 2: Actions at Breach Site									
1	Verbal comms within team	1			3	3	1	1	1	80
2	Stealth/Sound of own unit	3	3		4	1		4	2	73
3	Enemy voice/activity		1	3	1		3			52
4	Background noise		4		5	2	5			44
5	Radio comms with higher	4	2		2					37
6	Sound of successful breach	2	5					2		36
7	Sound of supporting units					4	2		4	35
8	Room acoustics from object thrown into room			2				3		25
9	Enemy weapons			4			4			22
10	Radio comms with supporting unit							5	3	22
11	Friendly grenade			1						14
12	Friendly weapons			5						10
	Phase 3: Room Clearing									
1	Verbal comms within team	2	2	1	2	3	1	1	1	107
2	Enemy voice/activity	1	3	2	4	2	4	4	4	96
3	Enemy weapons	4	1	4			5	2	3	71
4	Friendly weapons			3		1	3	3	2	63
5	Stealth/Sound of own unit		4		1	4			7	44
6	Radio comms with higher		5		3			5		32
7	Friendly grenade						2			13
8	Activity/movement of team	3								12
9	Radio comms within team				5					10
10	Movement of non-combatants								5	10
11	Background noise				6					9
12	Sound of supporting unit						6			9
13	Acoustics/echo							6		9
	Phase 4: Disengagement									
1	Verbal comms within team	1	2	1	2	3		1		80
2	Radio comms with higher	2	1		1	4		4		63
3	Enemy voice/activity		3	2				3		37
4	Enemy weapons			3		1				26
5	Background noises		4			2				24
6	Radio comms within team							2		13
7	Radio comms with supporting unit	3								12
8	Extraction platform		5							10

Table 2. Room Clearing Auditory Critical Cue Inventory

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IV. EVALUATION OF ROOM CLEARING SCENARIO

The next step in determining which auditory cues need to be included in a virtual room clearing scenario was to allow the room clearing subject matter experts to evaluate the current status of the auditory cues that were already modeled in the America's Army: Operations. The purpose of evaluating the sound cues from an expert's perspective was to determine if the auditory cues presented might lead to any negative transfer of training to the real-world execution of the task. Any inaccuracies in the cues that caused a player of the game to perform a task in a way that is not consistent with how an expert would actually conduct the task would lead to a negative training transfer issue. The game could be training a technique that would have to be retrained in the correct way in the real world. An analysis of the results obtained by evaluating the auditory cues in AA:O could be applied to the auditory cues in any virtual representation of the room clearing task.

In order to evaluate the room clearing auditory cues in AA:O, a hypothetical room clearing mission scenario was developed. This same mission was then presented to the SMEs in three different ways. Phase One had the SMEs use the same rank ordering technique of auditory cues that they used during the CDM interviews. The difference was that the scenario that they used for determining the importance of the cues was a hypothetical mission that they had not actually conducted in real life. Phase Two consisted of showing the SMEs a digital reproduction of the mission used in Phase One that had actually been conducted and recorded in AA:O. The SMEs watched the mission unfold and listened to the auditory cues that were presented as if they were actually playing the game. The SMEs then answered a series of questions about the accuracy and appropriateness of the auditory cues as well as any auditory deficiencies that they noticed. In Phase Three, the SMEs actually played the AA:O scenario that they had just watched and listened to in Phase Two. After playing the game, the SMEs discussed any potential training deficiencies that they expected would result from using the scenario as a training tool.

A. EVALUATION SCENARIO

The first step in creating the mission scenario to use for evaluating the AA:O auditory cues was to become familiar with all of the cues that were available in the game.

The goal was to have the recorded version of the scenario present as many auditory cues as possible for the SMEs to evaluate.

Working with the AA:O game developers, a hypothetical mission was created in which a four-man team was dropped off at a warehouse complex with one room being held by two enemy personnel. The four-man team was given a route of march through the courtyard of the warehouse complex as well as a breach point into the hostile room. Each man on the team was assigned a proposed route inside the room to reach his designated point of domination. Appendix B contains the Mission Briefing as well as a large scale map of the virtual warehouse complex showing the route of march leading to the room to be cleared and a smaller scale map of the room with the breach point and individual points of domination of each man inside the room. These basic maps had already been created as a level in the AA:O.

The next step was to record the execution of the scripted mission being played in the game so that it could later be played back to the SMEs. This recording process took eight people and a great deal of rehearsal and coordination. Four AA:O game developers each played the role of one of the friendly team members, two played the role of enemy combatants inside the room to be cleared, one ran the recording equipment, and the last served as overall coordinator of actions. Each player had certain actions to perform and phrases to say as the mission progressed.

The point of view for the entire operation was from the 3rd man in the team. The four-man team started at their initial location inside the warehouse complex. Each man charged his weapon. The first man (team leader) gave the verbal command "Squad, form up!" and each man replied in order with "Ready!" The team leader then commanded "Move out!" and the team moved in order along their designated route, through the open courtyard of the warehouse complex, to their stack position outside the room to be cleared. Once they reached their breach point, the team stopped momentarily and listened for any activity inside the room. There were two enemy players inside the room. One was silent and stationary and the other was moving, walking, and charging his weapon. The team leader whispered "Report in." and the other three team members answered "Ready." At this point the team leader moved forward to the door that was the designed breach point, prepared to throw a flask-bang grenade through the door,

announced “Grenade”, and threw the grenade into the room. The signal for the team to enter the room was the detonation of the grenade, and each man entered, moved along his route to his designated point of domination, and eliminated any enemy resistance in the room. The enemy players, while negatively affected by the flash-bang grenade, attempted to shoot the friendly team as they entered the room. Both enemy players were shot, and all four of the friendly team members reached their point of domination. Individual team members announced “Enemy spotted!” as they saw the enemy players and “Enemy down!” as they shot them. All four friendly team members announced “Area secure!” and the mission ended as the team leader commanded “Cease fire!”

The mission was recorded on a DVD from the point of view of the third man in the team. The recording captured all the visual effects as well as the auditory cues. Voice commands, weapon sounds, individual movement noises, and background sounds were all included in the recording.

B. PHASE ONE

Phase One of the evaluation process did not use the DVD recording or even the AA:O game. This phase consisted of the SMEs receiving a verbal mission briefing using paper copies of the scenario maps (see Appendix B). The verbal format was used to ensure that any aspects of the game itself did not influence this phase of the evaluation. Unlike the actual missions that were used for probing during the CDM interviews, this exercise was intended as an extension of the SMEs’ experience to a hypothetical room clearing mission. The SMEs were oriented to the maps and the mission was explained to them. Each SME understood that they were operating as the third man in the room clearing team. Just as in the CDM interviews, the mission was broken down into phases. This time, only the first three phases were used: movement to the breach site, actions at the breach site, and clearing of the room. Once each SME understood the mission and his particular part of the plan, they were given a list of all the auditory cues for the three phases of the operation and asked to rank-order the cues by importance as they had done during the interviews.

The reason this phase was included in the evaluation process was to ensure that all the SMEs were approaching this exercise with the mindset that it was a real exercise. The evaluations that the SMEs were going to be asked to make in phases two and three,

needed to be comparisons between the real-world execution of the task and what the AA:O game offered for auditory cues. The evaluations were not to be comparisons between AA:O and what the SMEs might have seen or heard in other games or virtual environments. Phase one was intended to ensure a comparison to the real world.

C. PHASE TWO

After discussing the relative importance of potential auditory cues for the operation during the first phase, the SMEs were shown the DVD reproduction of the mission that had just been examined. The entire mission was replayed five times in order to allow the SMEs to concentrate on certain auditory cues. They examined the voice communications, individual and unit movement sounds, weapons effects, acoustics of the surrounding area, and background noises. After all the SMEs were satisfied that they had a good appreciation of the quality of the auditory cues presented in the mission, they had a discussion of the accuracy and appropriateness of the audio cues. The SMEs were reminded that any comparisons should be made to the real-world auditory cues that they had mentioned during the first phase.

D. PHASE THREE

The third phase of the evaluation process allowed the SMEs to actually play America's Army: Operations. AA:O game developers continued to assume the role of the enemy and the three remaining friendly team members, while the SMEs rotated through playing the role of the number three man on the team, just as they had seen on the recorded version of the mission. Putting the SMEs into the game was intended to give the players a more immersive perspective than just watching the recorded mission version. After playing the game scenario of the mission, the SMEs were allowed to play other levels involving different scenarios in the game in order to give them a deeper appreciation of the auditory cues available in the game. They used different weapon systems, operated in different environments (forest, beach, jungle, tunnel), listened to different types of grenades, manipulated the different types of voice communications (shout, whisper, and radio), and heard different background noises. Not all of the environments and noises that the SMEs experienced in these different levels of the game related directly to the scenario that we had developed, but playing the different levels

allowed the SMEs to experience the auditory cues that could be presented in a different room clearing scenario that might take place in a different environment.

Once the SMEs were done experiencing the AA:O audio cues first hand, they discussed their overall impressions of the game and its auditory cues as well as any real-world training deficiencies that they felt someone would have if the game was used as their sole training method. The SMEs were asked to focus their discussion on any potential negative training transfer issues that they would expect to see as a result of the game audio.

E. EVALUATION RESULTS

The results of rank-ordering the Critical Cue Inventory using the evaluation scenario are shown in Table 3. Although there are some minor changes to the ranking of some of the individual auditory cues from the CDM ranking, these changes are explained by the fact that in the hypothetical evaluation scenario, there were no supporting or overwatching units, and there was no radio communications with a higher headquarters. With the exception of those changes, the trend to rank a particular auditory cue high or low was almost identical to the results generated by the interviews. This indicates that the SMEs were able to extend their expertise to the hypothetical scenario and evaluate it in the same way that they evaluated their real-world training scenarios during the CDM interviews.

RANK		RANK	
	Phase 1: Movement to Breach Site		**Phase 3: Room Clearing**
1	Enemy voice/activity	1	Verbal comms within team
2	Enemy weapons	2	Enemy voice/activity
3	Verbal comms within team	3	Enemy weapons
4	Stealth/Sound of own unit	4	Friendly weapons
5	Background noise	5	Activity/movement of team
6	Radio comms within team	6	Acoustics/echo
7	Radio comms with higher	7	Friendly grenade
8	Supporting unit weapons	8	Movement of non-combatants
		9	Background noise
	Phase 2: Actions at Breach Site	10	Radio comms within team
1	Enemy voice/activity	11	Stealth/Sound of own unit
2	Verbal comms within team	12	Sound of supporting unit
3	Stealth/Sound of own unit	13	Radio comms with higher
4	Enemy weapons		
5	Friendly grenade		
6	Room acoustics from object thrown into room		
7	Sound of successful breach		
8	Friendly weapons		
9	Background noise		
10	Radio comms with supporting unit		
11	Radio comms with higher		
12	Sound of supporting units		

Table 3. Evaluation Scenario Critical Cue Inventory

The discussions of the accuracy and appropriateness of the auditory cues presented in America's Army; Operations revealed many insights as to what an expert expects to hear in a virtual training scenario. The largest criticism that the SMEs had with the auditory cues was the lack of emotional response that the cues created. The overwhelming majority of comments indicated that the audio cues need to be louder and need to have more of an emotional and physical impact on the user. Grenades detonating and weapons firing, especially in a confined area like inside a room, need to drown out all other sounds for a prolonged period. The SMEs agreed that the emotional aspect of entering a room containing hostile enemy soldiers would have a profound impact on your ability to hear. They felt that the amount of adrenalin produced by this type of mission would certainly make the team members breath hard, which would also muffle additional sounds. The SMEs mentioned an interesting point relating to the emotional aspect of the scenario created by the background noises. Background noises ranked relatively low in

importance on the Critical Cue Inventories, but during the discussions, the SMEs mentioned that one good way to increase the emotion and immersion of the user is to have more background noises. These background sounds need not relate to the actual room clearing mission, but must merely be accurate for the setting in which the mission takes place. The SMEs felt that creating an emotional immersion in the user was critical for accurate training, and that accurate background noises definitely increased their emotional level and immersion. The lack of background noises precluded an emotional immersion by all the SMEs.

An individual's voice in the game is another area that the SMEs felt needed additional work and could lead to negative training if cot corrected. Similar to the points mentioned above, the SMEs felt that it is critical to allow the users to display a wider range of emotion as they speak in the game. Verbal communications within the team members ranked the highest in importance during the CDM interviews. The SMEs agreed that the importance of these voice communications comes not only from what is said, but also from the way it is said. Whispers need to be softer, and yells, especially during the actual room clearing phase, need to be louder and convey the emotional aspects that would be expected with such a high-intensity activity. Additionally, the options of available voice commands needs to accurately reflect the current Standard Operating Procedures of the unit conducting the operation. The SMEs felt limited by the number of available voice commands that they could choose to say.

The final area that the SMEs felt needed to be improved was the amount of noise that individuals and their equipment make as they move and operate in the virtual world. An individual's ability to determine the level of stealth of himself and his unit ranked high in the Critical Cue Inventories and was of paramount importance during most phases of the CDM interviews. Although the virtual players in the scenario did make noise as their feet touched the ground, the SMEs were expecting a much more robust set of individual movement and equipment noises. They all felt that their packs and equipment would rattle somewhat, ammunition would rattle in plastic magazines, helmet snaps would make noises, their own heavy breathing would be hard to control, and their own footfalls would be much louder than what they experienced in the game. Not only are

these cues essential in determining you own level of stealth, but also they are the means by which the friendly unit can gain information on any enemy movement or activity.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

This thesis has examined the issue of determining which auditory cues need to be presented in a virtual training environment. The task of conducting a Close Quarters Combat Room Clearing Operation is extremely complex, difficult, and dangerous. As increasing technology in the virtual environment domain allows for such tasks to be trained with these technologies, great care must be taken to avoid any negative training issues.

The Critical Decision Method of knowledge elicitation allows investigators to use the great store of knowledge possessed by subject matter experts in order to improve training techniques. A structured interview, built on the framework of the Critical Decision Method, and administered to SMEs in the room clearing domain, resulted in a list of auditory cues, prioritized by importance, for each phase of the task.

This prioritized list of auditory cues, or Critical Cue Inventory, was used by room clearing SMEs to evaluate the auditory cues that are currently being presented during room clearing scenarios in the game America's Army: Operations. This expert evaluation included a discussion of potential negative training issues that could result from the game's auditory cues. Any lessons learned from the example room clearing scenario in AA:O can be extended to other attempts at representing the room clearing task in a virtual environment. The scenario in AA:O was merely used as one example of a virtual representation of a task. These lessons should be incorporated into any future attempts to create a virtual MOUT trainer or a virtual trainer of any complicated task.

B. RECOMMENDATIONS

All attempts at replicating a complex task in a virtual environment must involve an analysis of the audio cues associated with the real-world performance of that task. Ideally, the importance of accurate auditory cues would be recognized early, and the analysis of those auditory cues would occur during the initial Cognitive Task Analysis used to define the task. This way, one analysis could be done that addressed all the cues used during the execution of the task, and a separate analysis of the auditory cues would not need to be conducted. The Critical Decision Method is just one of many ways to

assist subject matter experts in recalling and explaining the auditory cues associated with a task. Carefully thought out and worded probing questions can help the SMEs to determine which of the auditory aspects of the task are most important to the successful execution of the task and can result in a rank-ordered Auditory Critical Cue Inventory. That Auditory CCI should determine the priority of auditory cues included in the virtual representation of the task.

This process, applied to the Close Quarters Combat Room Clearing task, and evaluated through the sound cues presented in America's Army: Operations, resulted in a recommendation to improve three aspects of the auditory cues in the game. The first recommendation is to try to illicit more of an emotional response through the use of auditory cues. Loud sounds such as grenades and weapons firing should be louder and have more of an impact on the player, yells during combat should sound more emotional, the effect of adrenalin causing hard or heavy breathing should be modeled, and the emotional impact from simple background noises creating a sense of immersion are all critical to creating an emotional impact on the user. The second recommendation is to widen the range of options for verbal communications within the game. The phrases that virtual players are capable of saying must match the established procedures of real-world experts. Similar to the first recommendation, these voice communications need to be able to be said in a wider range of emotional ways. Whispers should be softer, yells should be louder, and the emotional state of the player making the verbal communication should be able to be discerned by those hearing his voice. The pre-recorded voice communications should be categorized by the overall emotional level expected for a particular operation. For example, while conducting actions at the breach site, stealth is of utmost importance to the room clearing team. During this phase the player should be able to select from a list of phrases that reflect that concern. Once the team enters the room, however, a menu of yelled or screamed voice communications should be used to try and demonstrate the user's highly aroused state. The final recommendation pertaining to the auditory cues in a virtual room clearing operation, is to continue to add well-modeled audio cues for equipment used by the virtual players. Rucksacks and equipment should rattle in a realistic way, ammunition should make a sound when it is moved inside a magazine, and everyone close to a running player should hear footfalls. These sounds

are key to determining your own level of stealth and to determining the activity of the enemy.

By eliciting knowledge from domain experts and using their expertise to evaluate the accuracy and appropriateness of auditory cues in a training virtual environment, designers of training systems can ensure that the auditory cues presented in the virtual scenario will not lead to any negative transfer of training.

C. FUTURE WORK

Although this study concentrated on the auditory cues associated with a room clearing operation, the same procedures could be applied to any task that is to be represented and rained in a virtual environment. Any training conducted in a virtual environment has the potential to produce a negative training effect if all the aspects of the virtual training are not thoroughly investigated and their impact on the individual's training analyzed. This detailed analysis of auditory cues should be conducted for every virtual training task.

In the future, the same evaluation procedure used in this study should be applied to room clearing operations conducted in other virtual environments such as the Navy and Marine Corps project called VIRTE (Virtual Technologies and Experiments). VIRTE is being designed as a fully immersive combat trainer and its ability to accurately present the auditory cues associated with any training task will be critical to its ability to conduct quality training.

Although all of the SMEs used during this study had received extensive room clearing training, they were all students at the Naval Postgraduate School at the time the interviews and scenario evaluation were conducted. Some of the SMEs had conducted room clearing operations as recently as three months prior to the interviews, but some had not conducted an operation in the past five years. While the Critical Decision Method allowed all the SMEs to recall a great deal of information relating to the auditory aspect of the operation that they selected, future work should include using experts that are currently assigned to units with a room clearing mission. This process would allow a comparison and evaluation of the SMEs ability to recall auditory cues used during room clearing operations that they had conducted in the past.

Another method of obtaining the auditory cues associated with the room clearing task would be to equip soldiers with recording devices as they conduct a live-fire room clearing training exercise. Subject matter experts could then use those recorded auditory cues to validate and possibly enrich the Critical Cue Inventory created from the Critical Decision Method interviews.

APPENDIX A. INTERVIEW

A. INTRODUCTION

Subject Number: _____

My name is MAJ Tom Greenwald, a Simulations Operations Officer in the U.S. Army and a MOVES student at the Naval Postgraduate School. You were asked to participate in this interview because you are a subject matter expert in the domain of MOUT Close Quarters Combat Room Clearing Operations. I will use the information obtained during this interview to help me develop an experiment that will be used as my Master's Thesis at the NPS.

The purpose of my Thesis is to examine the auditory cues associated with a MOUT room clearing operation and determine which of those cues need to be included in a virtual environment representation of the operation, what sound cues are associated with the performance of the actual task, and if the lack of certain auditory cues will result in a detriment of task performance.

This interview will focus on a time that you actually conducted a room clearing operation and will attempt to determine what auditory cues you had available to help you in conducting the task, what cues you used, what cues you did not use, and an ordering of the cues from most important to least important for each phase of the operation.

This interview was constructed using the Critical Decision Method (CDM) of knowledge elicitation, which will result in a Critical Cue Inventory of auditory cues. The CDM is composed of five steps that we will use: 1) Select the incident. 2) Obtain unstructured incident account. 3) Construct incident timeline. 4) Identify decision points/phases. 5) Probe decision points/phases. Our sixth and final step will be to rank order the auditory cues for each phase of the operation by importance.

B. BACKGROUND INFORMATION

Before we begin I need to gather some background information.

Age: _____ Service: _____ Years in service: _____ Branch/MOS: _____

Number of years experience in MOUT Room Clearing Operations: _____

C. SELECT THE INCIDENT

I would like you to bring to mind an occasion when you conducted a room clearing operation. If possible, I would like it to be a time when you used the Precision room clearing technique rather than the High Intensity technique. This should be an operation that offered minimal information prior to its execution; one in which there was the possibility of having noncombatants in the room to be cleared, the number and location of enemy forces was unknown, and if possible, one in which you not familiar with the content and exact layout of the room to be cleared. Try to select an operation

that was a challenge to you, that offered numerous auditory cues, and one in which your decisions and actions lead to a successful outcome.

D. OBTAIN UNSTRUCTURED INCIDENT ACCOUNT

I would now like you to tell me the story of that room clearing operation. Give me a brief description of the background leading to the mission and then tell me everything you remember from the time you initiated movement until the end of the operation. I will listen and take a few notes and will only interrupt you if I need clarification. It may help you to draw a map or sketch as you go.

E. CONSTRUCT INCIDENT TIMELINE

Now I would like you to help me as I make a timeline of the operation. Tell me if I miss something or if I get the sequence or duration of any event wrong.

F. IDENTIFY DECISION POINTS/PHASES

Now I would like to divide our timeline that we just created into four separate phases:

5. Plan, prep, and movement to breach site.
6. Creation of breach.
7. Clearing of the room.
8. Disengagement.

G. PROBE DECISION POINTS/PHASES

Now we have our timeline of your mission broken down into four phases. I will now ask you a series of questions about each of these phases and the auditory cues that you had available and how you used them.

During Phase ____

1. What auditory cues helped you determine the answer to the following questions:

   a. Where am I (in respect to the urban area or my assigned sector)?

   b. Where are my soldiers? What is their current status/activity?

   c. Where are friendlies (adjacent and supporting units)? What is their current status/activity?

   d. Where is the enemy? What are the enemy's capabilities?

2. What was your primary concern during this phase?

3. What were you primarily listening to or for?

4. Did the actual execution of this phase differ from the plan?

   a. If it did differ, how were you able to recover?

   b. Did your ability to recover have anything to do with auditory cues?

5. Was there any background noise?

   a. What was it?

b. Did it impact in any way on your ability to conduct the mission?

6. What was the most important piece of information that you did not have?

a. Could you have received this information in the form of an auditory cue?

b. What would have had to change in order for you to have received this cue?

7. Name one thing that you wished you could hear but could not.

a. Why couldn't you hear it?

8. Name one thing that you wished you could not hear.

a. What negative impact did this unwelcome cue have?

9. How important was the stealth of the friendly force during this phase?

10. How much information do you think you were able to discern based on the acoustics of the room or area of operation?

11. How much of an impact did extremely loud noises (weapons firing, grenades) have on your ability to successfully complete this phase?

12. How much of an impact did the auditory cues have on your ability to maintain situational awareness during this phase?

13. Which auditory cues aided or detracted from your situational awareness during this phase?

H. RANK ORDER AUDITORY CUES

We will now review the auditory cues that you mentioned during the proceeding questions. When we are done I want you to prioritize those cues according to the impact that they had on your ability to successfully complete this phase of the operation. Remember that the importance of an auditory cue could come from the fact that you were or were not able to hear something, or it could come from the fact that the enemy was or was not able to hear something.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____

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APPENDIX B. MISSION BRIEFING AND MAPS

A. MISSION BRIEFING

Orient everyone to maps

Enemy Situation:

- There are an unknown number of enemy forces in the designated room.
- Enemy equipment and weapons are unknown.
- All other areas of the complex are secure.

Friendly Situation:

- It is unknown if there are any non-combatants in the room.
- There are no supporting units.
- There are no overwatching units.
- You are the third man in a 4-man team.
- You are equipped with standard infantry weapons, an M-16, fragmentation grenades, and flash-bang grenades.

Mission:

Your 4-man team will move from the SP, along the designated route, to the point of entry into the room. Upon reaching the point of entry, the first man will deploy a flash-bang grenade through the open door. All team members will enter the room, reach your designated point of domination, and eliminate all enemy resistance.

Coordinating Instructions:

- Your team has squad radios and internal voice communications available.
- Exercise as much stealth as possible until the flash-bang signal to enter the room.
- Try to gain as much information as possible about the enemy situation and any non-combatants in the room prior to entry.
- End of mission will occur when the room is deemed clear of all enemy.

B. LARGE SCALE SCENARIO MAP

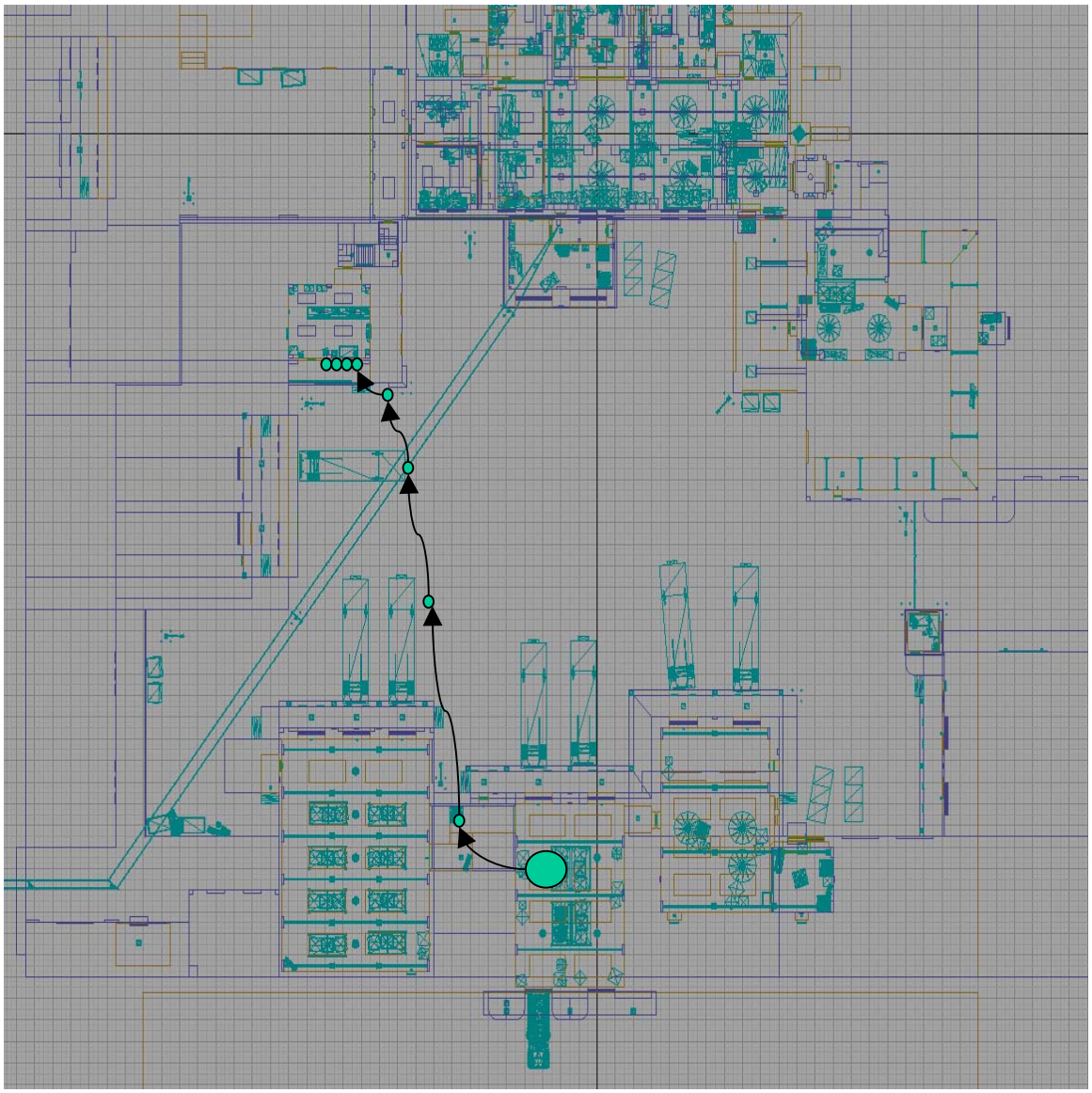

Figure 1. Large Scale Scenario Map

C. SMALL SCALE SCENARIO MAP

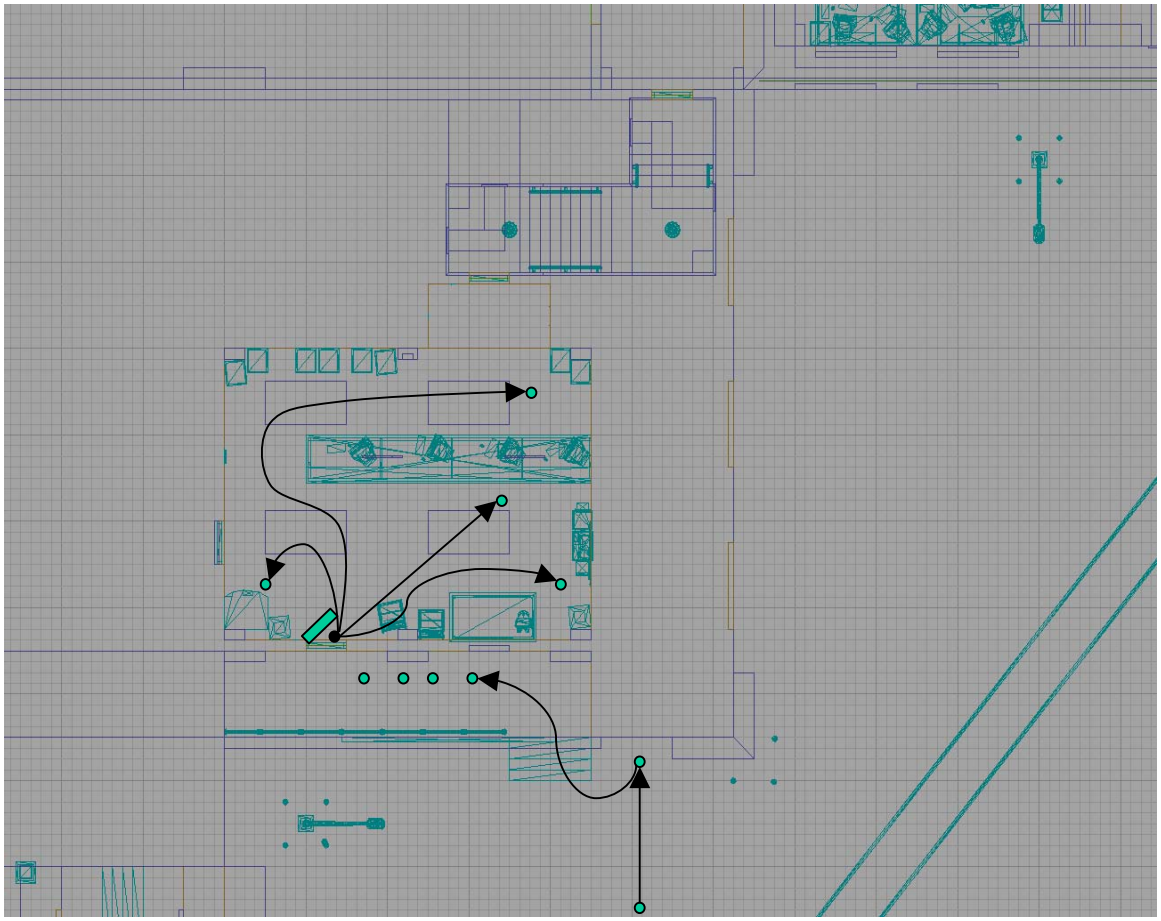

Figure 2. Small Scale Scenario Map

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APPENDIX C. PARTICIPANT CONSENT FORMS

1. **Introduction.** You are invited to participate in a study exploring the auditory cues associated with a Close Quarters Combat Room Clearing Operation. This research is aimed at improving sound systems in virtual environments. . Your recorded data will be used in an effort to determine which cues need to be included in a virtual environment representation of the subject task. You will participate in one of two phases of this research:

a. Phase One is a knowledge elicitation interview in which you will be asked a series of questions relating to the auditory cues you used to conduct an actual room clearing operation in the past.
b. In Phase Two, you will be playing a scenario in America's Army: Operations. After the scenario you will complete a questionnaire to indicate how the auditory cues presented impacted on your ability to complete the mission.

2. **Background Information.** Data is being collected by the Naval Postgraduate School's Human System's Integration Laboratory for use in developing virtual environments.

3. **Procedures.** If you participate in Phase One of this study, the researcher will ask you to recall and explain a time when you conducted a room clearing operation. You will be asked a series of questions relating to the auditory cues that you used during the conduct of that task. This entire task will take approximately 60 minutes. If you participate in Phase Two of this study, you will use the mouse and keyboard to play an America's Army: Operations game scenario. You will then complete a written questionnaire. This entire task will take approximately 30 minutes.

4. **Risks and Benefits.** The interview and experiments involve no risks to individuals, however, IF YOU FEEL UNCOMFORTABLE WITH THE INTERVIEW OR THE GAME SCENARIO AT ANY TIME, PLEASE INFORM THE EXPERIMENTER AT ONCE AND DO NOT PROCEED ANY FURTHER. The benefits to the participants will be to contribute to current research in advancing virtual environments and in human-computer interaction.

5. **Compensation.** No tangible reward will be given. A copy of the results will be available to you at the conclusion of the experiment.

6. **Confidentiality.** The records of this study will be kept confidential. No information will be publicly accessible which could identify you as a participant.

7. **Voluntary Nature of the Study.** If you agree to participate, you are free to withdraw from the study at any time without prejudice. You will be provided a copy of this form for your records.

8. **Points of Contact.** If you have any further questions or comments after the completion of the study, you may contact the research supervisor, Dr. Russell Shilling (831) 656-2543 shilling@cs.nps.navy.mil.

9. **Statement of Consent.** I have read the above information. I have asked all questions and have had my questions answered. I agree to participate in this study.

---------- ----------
Participant's Signature Date

---------- ----------
Researcher's Signature Date

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943 MINIMAL RISK CONSENT STATEMENT

Participant:

VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: An Analysis of Audio Requirements for a Virtual Environment Close Quarters Battle Room Clearing Operation.

1. I have read, understand and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and if so, what they consist of, or where further information may be obtained.

7. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to pertinent questions about the research is Professor Russell Shilling, Principal Investigator, and about my rights as a research participant or concerning a research related injury. A full and responsive discussion of the elements of this project and my consent has taken place.

_____ _____

Signature of Principal Investigator Date Signature of Volunteer Date

_____

Signature of Witness Date

PRIVACY ACT STATMENT
NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Authority: Naval Instruction

2. Purpose: ANALYZE THE AUDITORY CUES USED DURING A CLOSE QUARTERS COMBAT ROOM CLEARING OPERATION

3. Use: Response data will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. The Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act may grant use of the information to legitimate nongovernmental agencies or individuals.

4. Disclosure/Confidentiality:

a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number, which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the crossreference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which are not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

c. I also understand that disclosure of the requested information is voluntary.

_____

Signature of Volunteer Name, Grade/Rank, DOB Date

_____

Signature of Witness Date

LIST OF REFERENCES

Aronson, W. (2002). *A Cognitive Task Analysis of Close Quarters*. Master's Thesis, Naval Postgraduate School, Monterey, CA.

Berry, D. (1987). The Problem of Implicit Knowledge. *Expert Systems*, vol. 4.

Broadbent, D., Fitzgerald, P., & Broadbent, M. (1986). Implicit and Explicit Knowledge in the Control of Complex Systems. *British Journal of Psychology*, vol. 77.

Department of the Army. (2002). *Combined Arms Operations in Urban Terrain (FM 3-06.11)*. Washington, D.C.: Author.

Gammack, J., & Young, R. (1985). Psychological Techniques for Eliciting Expert Knowledge, in Bramer, M. (ed). *Research and Development in Expert Systems*. Cambridge University Press.

Hawkins, D. (1983). An Analysis of Expert Thinking. *International Journal of Man-Machine Studies*, vol. 18.

Hogarth, R. (1974). Process Training in Critical Judgment. *Behavioral Science*, vol. 19.

Holman, T. (2000). *Surround Sound Up and Running*. Focal Press.

Johnson, P. (1983). What Kind of Expert Should a System Be? *Journal of Medicine and Philosophy*, vol. 8.

Kidd, A. (1987). *Knowledge Acquisition for Expert Systems: A Practical Handbook*, Plenum Press.

Klein, G., Calderwood, R., & MacGregor, D. (1989). Critical Decision Method for Eliciting Knowledge. *IEEE Transactions on Systems, Man, and Cybernetics*, vol. 19, no. 3.

Lessiter J., Freemen J., & Davidoff J. (2001). Really Hear? The Effects of Audio Quality on Presence, *paper presented at the 4th International Workshop on Presence*, Philadelphia, PA.

McGraw, K., & Reiner, A. (1987). Task Analysis: Structuring the Knowledge Acquisition Process. *TI Technical Journal*, November-December 1987.

Olson, J. & Rueter, H. (1987). Extracting Expertise from Experts: Methods for Knowledge Acquisition. *Expert Systems*, August 1987.

Patterson, C. (1990). *Cognitive Feedback as a Tool for Knowledge Acquisition*. Master's Thesis, Naval Postgraduate School, Monterey, CA.

Phillips, J., McCloskey, M., McDermott, P., Wiggins, S., Battaglia, D.,Thordsen, M., & Klein, G. (2001). *Decision Centered MOUT Training for Small Unit Leaders (Research Report 1776)*. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Pickles, J. (1982). *An Introduction to the Physiology of Hearing*, Academic Press.

Riesbeck, C. (1984). Knowledge Reorganization and Reasoning Style. *Developments in Expert Systems*, Academic Press.

Salter, M., Eakin, D., & Knerr, B. (1999). *Dismounted Warrior Network Enhanced Restricted Terrain (DWN ERT): An Independent Assessment (Research Report 1742)*. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Sanders, R. & Scorgie, M. (2002). *The Effect of Sound Delivery Methods on a User's Sense of Presence in a Virtual Environment*. Master's Thesis, Naval Postgraduate School, Monterey, CA.

Sulzen, R. (1997). *Selected Training Practices for Military Operations in Urban Terrain (MOUT) (Research Report 1716)*. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Stevens, S. & Davis, H. (1938). *Hearing, Its Psychology and Physiology*, John Wiley & Sons.

Vince, J. (2001). Essential Virtual Reality Fast, 3rd ed. Springer-Verlag. U.S. General Accounting Office. (1991). *Using Structured Interviewing Techniques, methodology transfer paper 10.1.5.* Washington, D.C.

Wever, E. (1949). *Theory of Hearing*, John Wiley & Sons.

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   Monterey, California

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   Modeling, Virtual Environments & Simulation Institute
   Naval Postgraduate School
   Monterey, California

5. Dr. Rudolph P. Darken
   Modeling, Virtual Environments & Simulation Institute
   Naval Postgraduate School
   Monterey, California

6. MAJ Dave Laflam, USA
   Army Model and Simulation Office
   Office of the Deputy Chief of Staff for Operations and Plans
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